Assessing Boreal Forest Burn Severity using UAS-based Photogrammetric Mapping

Robert H. Fraser [1], Jurjen van der Sluijs [2], and Ronald J. Hall [3]

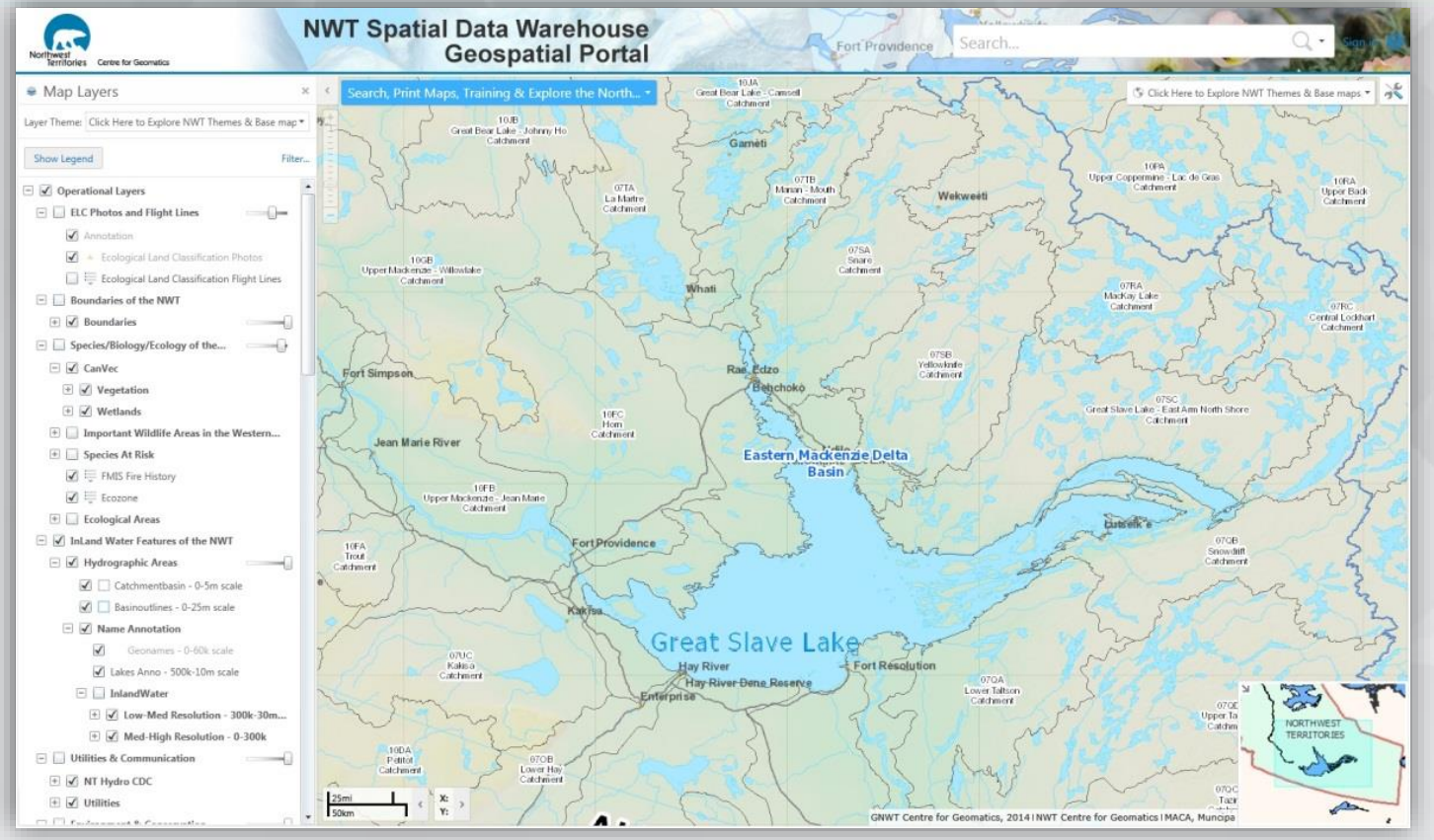
[1] Canada Centre for Mapping and Earth Observation, Natural Resources Canada
[2] NWT Centre for Geomatics, Government of the Northwest Territories
[3] Canadian Forest Service, Natural Resources Canada

Natural Resources Canada | Ressources naturelles Canada
Canada Centre for Remote Sensing | Centre canadien de télédétection

Government of Northwest Territories

WHO ARE WE?

NWT CENTRE FOR GEOMATICS



OGC®
Making location count.

Caching

WMS

WCS

Geocortex®

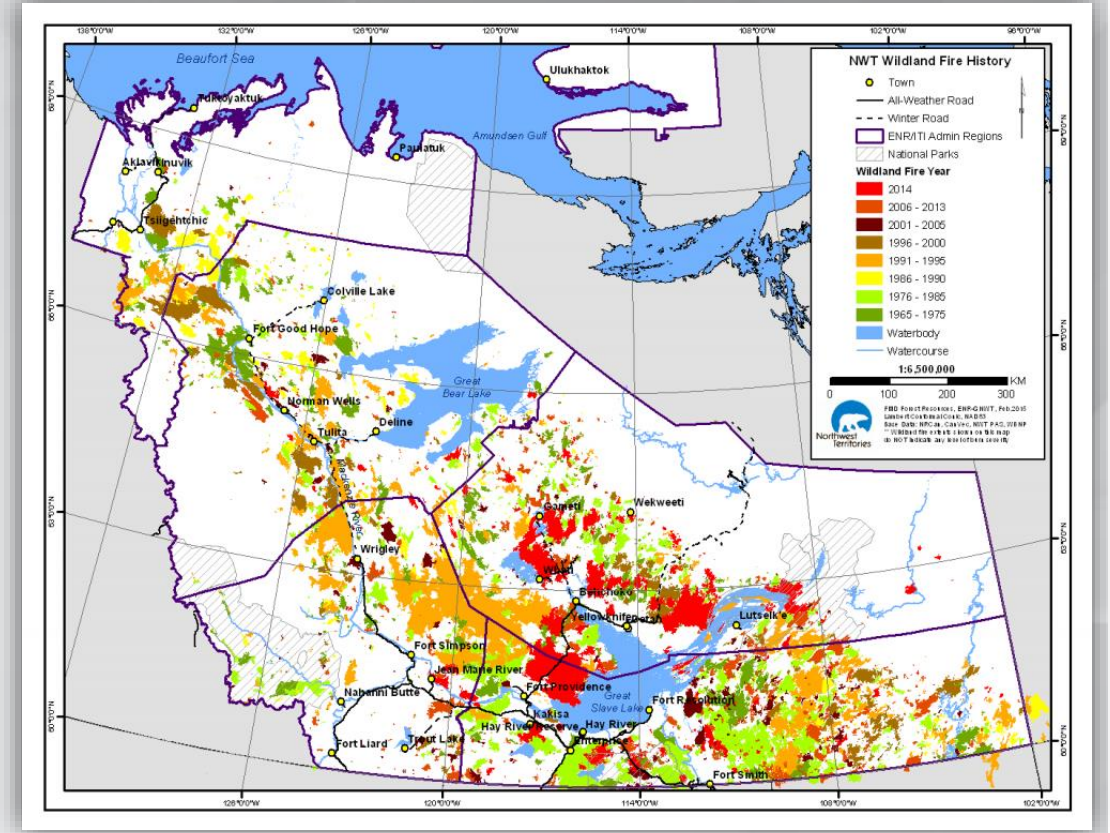
Data Management
Access to geospatial data
Conduct mapping/analysis projects
Establish information systems
Provide training, resources, and advice

Government of
Northwest Territories

NWT FIRE REGIME

- Average: 274 wildfires / year
- Average: 600,000 ha
- Cause: 88% lightning

- 2014 wildlife season:
  - 380 fires, 3.4 million ha
  - South Slave
    and North Slave region



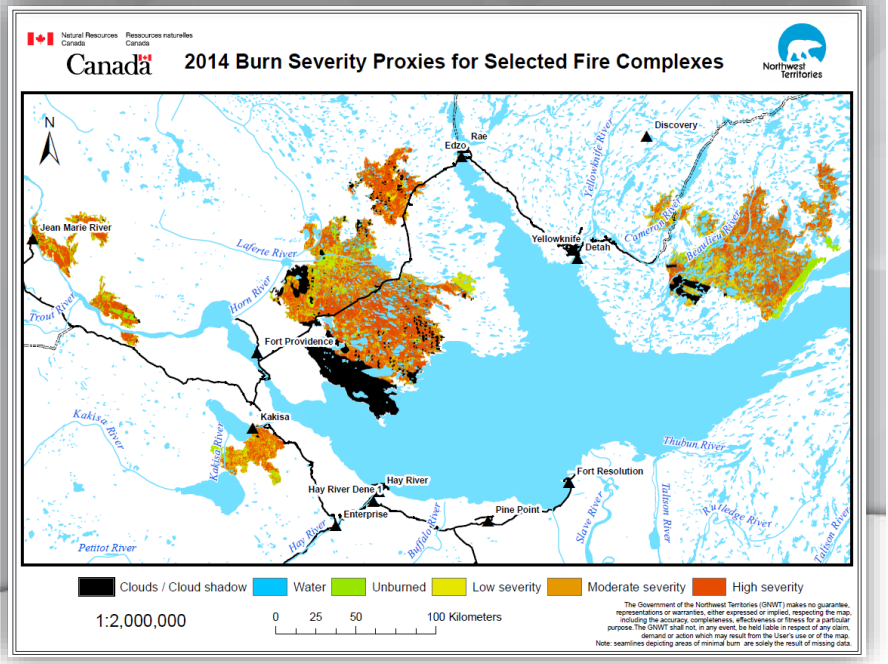
http://www.enr.gov.nt.ca/state-environment/143-annual-area-burned-and-number-fires

Government of
Northwest Territories

NWT FIRE RESEARCH FRAMEWORK

- Large areas partially burned:
  - Wildlife responses?
  - Permafrost thaw/subsidence?
  - Community salvage logging?
  - Post-fire regeneration?

- Immediate information needs:
  - Maps of (un)burned areas
  - Maps of canopy severity
  - Maps of surface severity
  - Ground-truthing of maps



Baltzer, J., and Johnstone, J. (2015). The 2014 NWT Fires – Developing a Research Framework. Unpublished.

RESEARCH VALUE PROPOSITION:
CONVENTIONAL APPROACH

1. Plot-scale Composite Burn Index (Key and Benson, 2006)

2. Differenced Normalized Burn Ratio (dNBR) versus CBI
   - Boreal: non-linear relationship (Adjusted R^2 = 0.82-0.85, Hall et al., 2008)

3. Thresholding to obtain severity maps

Challenges:

- Subjective/qualitative CBI ratings; esp. medium severity
- Complex relationships between integrated CBI indicators and reflectance
- Expensive field-data collection (±10 x $ compared to south)
- No continuous structural vegetation maps

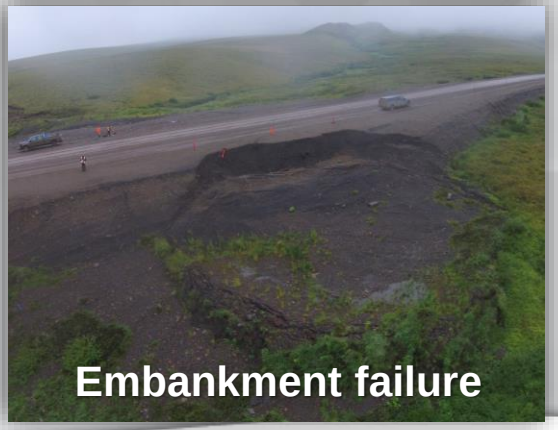
Government of
Northwest Territories

Hall, R.J., et al. (2008). Remote sensing of burn severity: experience from western Canada boreal fires. International Journal of Wildland Fire 17(4): 476-489

WHY UNMANNED AIRCRAFT SYSTEMS (UAS)?

- ❑ Reduce risk to staff
- ❑ Improves situational awareness
- ❑ Reduce workload / cost
- ❑ Increase data detail

Goal: To develop UAS burn severity indices to scale detailed ground-to-satellite measurements



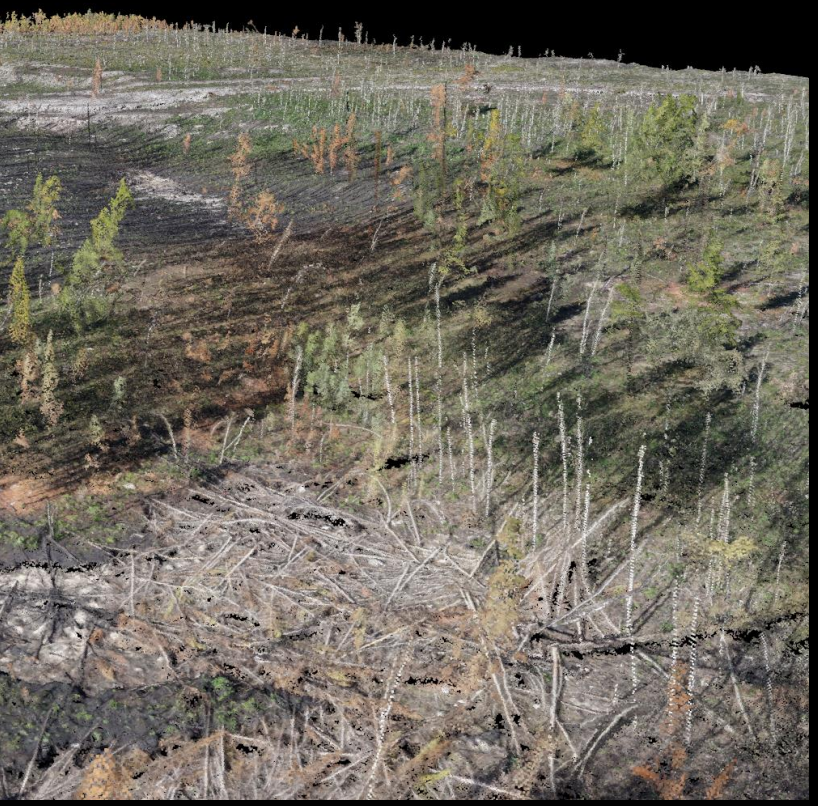
METHODS:

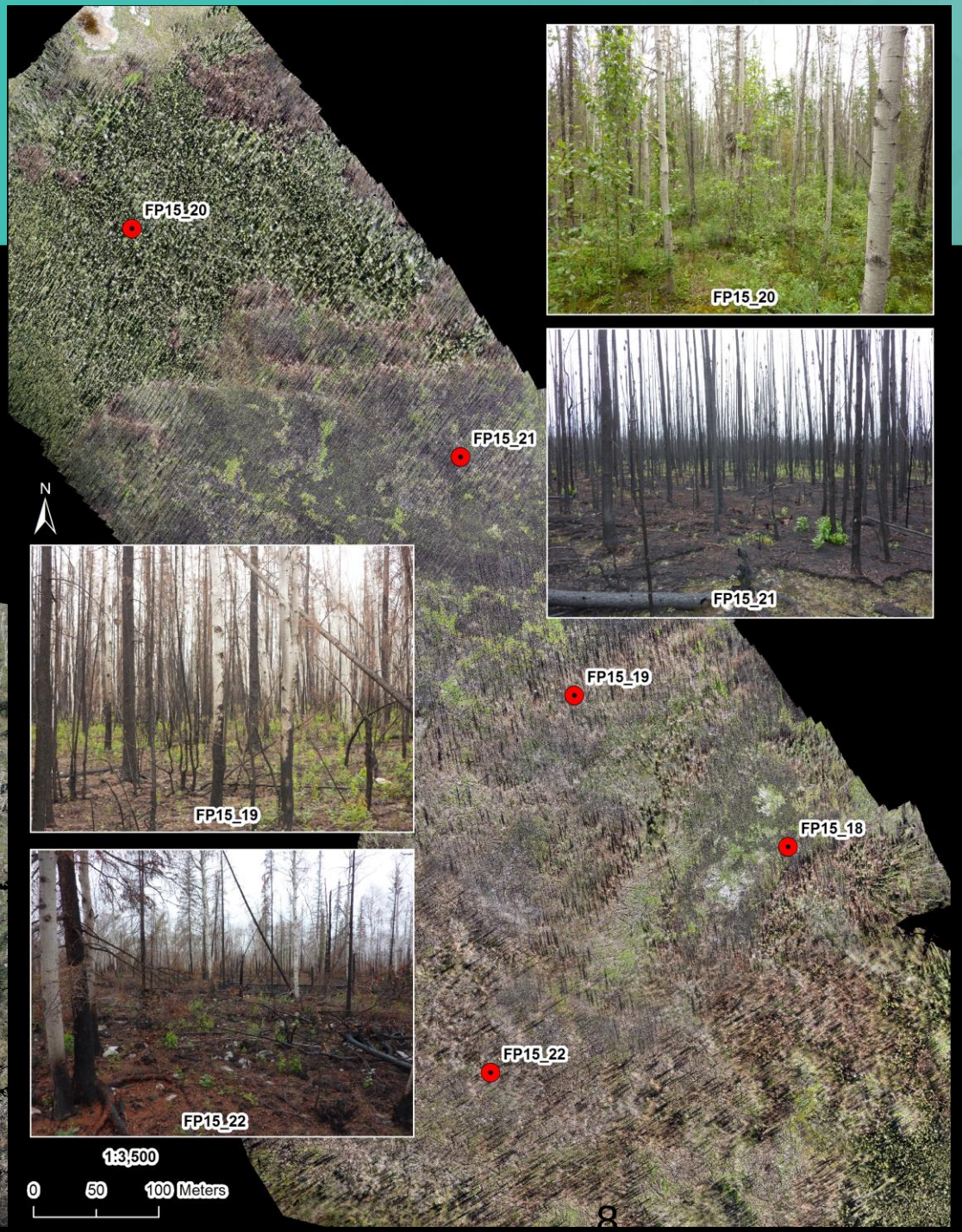
EQUIPMENT, DATA ACQUISITION, DATA PROCESSING

METHODS:
DATA EXPLORATION

# Forest Inventory Units	Dominant Tree Species
12	Sw, Sb, A
2	Pj
5	Pj, Sw, Sb

Dense Point Cloud (>1,400 pts / m²)





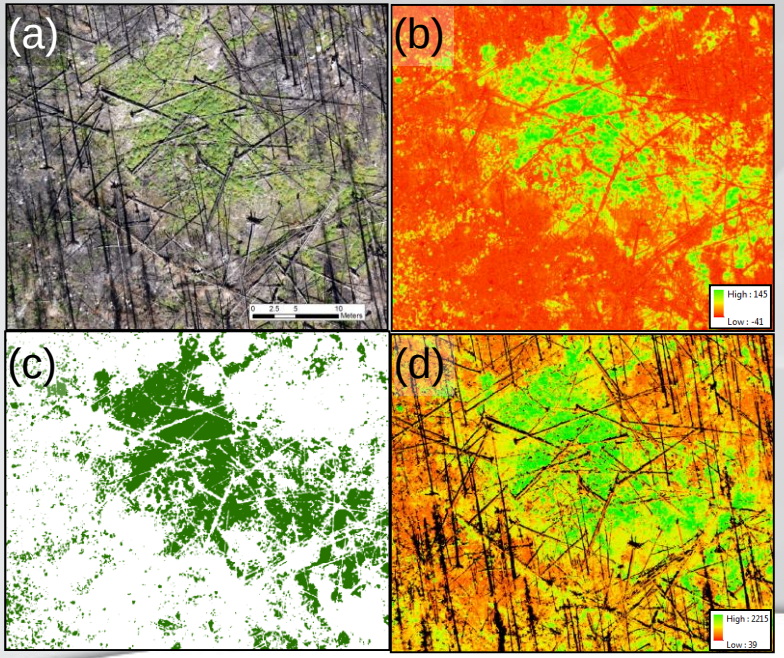
METHODS:

SPATIAL ANALYSIS: SPECTRAL INDICES

Focus on basic indicators (residual green vegetation / charred surface)

1. Classify into binary burned vs. green vegetation
   - UAS spectral index: "**Excess Greenness**" = 2 * Green – Red – Blue

2. Classify Charred Surface
   - New UAS spectral index: "**Char Index**"
     - Low visible brightness (R + G + B)
     - "Flat" spectrum with lack of colour:
       Max(|B-G|, |B-R|, |R-G|)
     - Char Index = Brightness + (MaxDiff x 15)
   - Shadow masked based on red band



METHODS:

SPATIAL ANALYSIS: BURN SEVERITY INDICATORS

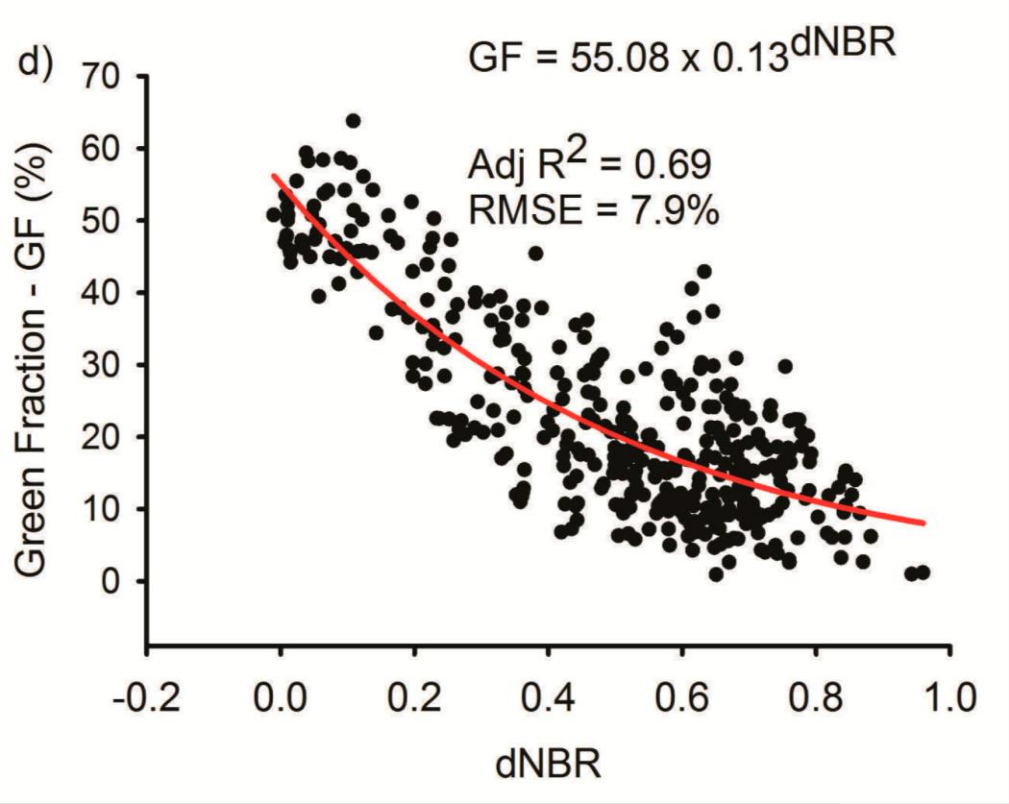
1. UAS Indicators aggregated to 30 m Landsat pixels:
   - **Fraction of Green Vegetation**
   - Fraction of Green Crown Vegetation (5 m threshold of Canopy Height Model)
   - **Fraction of Charred Surface**

2. Landsat Indicators :
   - Normalized Burn Ratio (NBR), post-fire
   - Differenced NBR (dNBR)

- Predict UAS indicators using Landsat variables
  - Random selection; 70% cal. (n = 388), 30 % val. (n =167)
  - Wilcoxin signed-rank test for statistical differences (5% level of significance)

RESULTS:

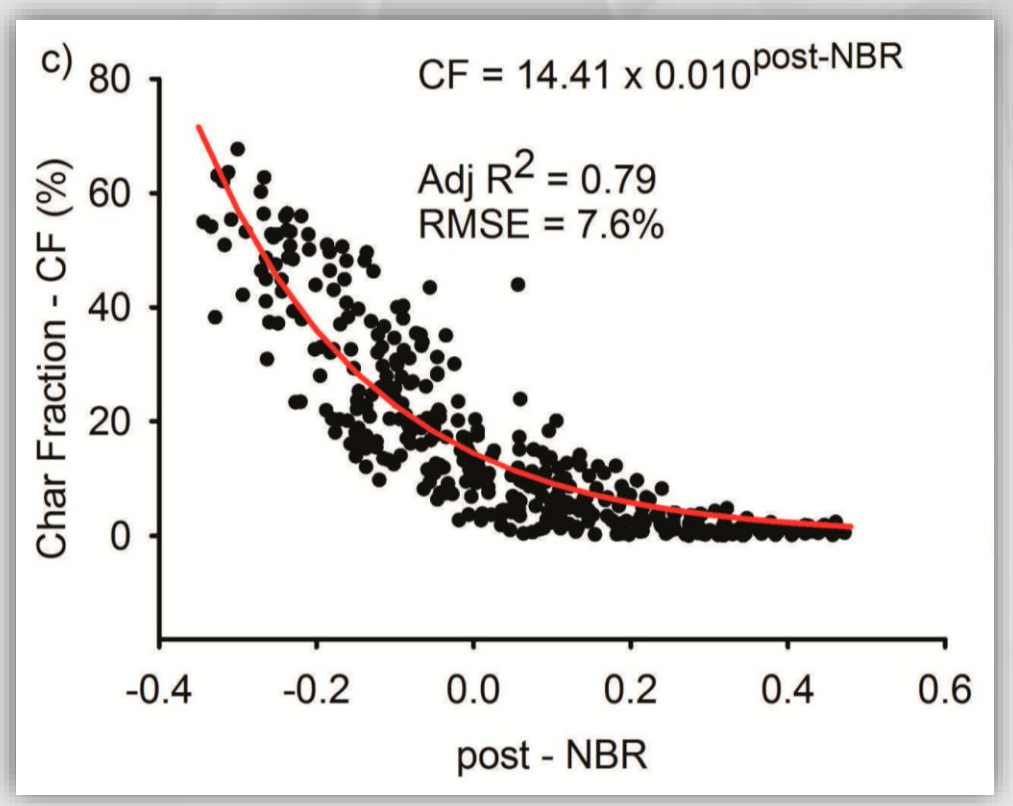
RESIDUAL GREEN VEGETATION

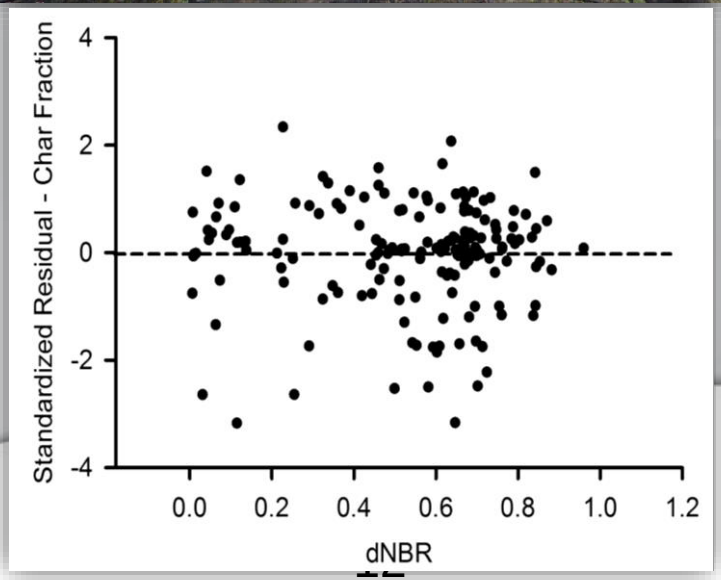


Wilcoxin p = 0.93

RESULTS:

CHARRED SURFACE



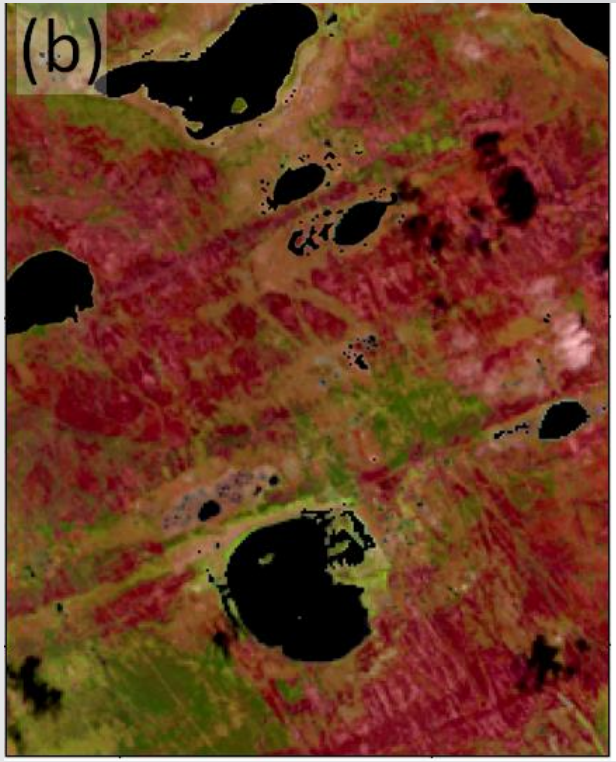


Wilcoxin p = 0.29

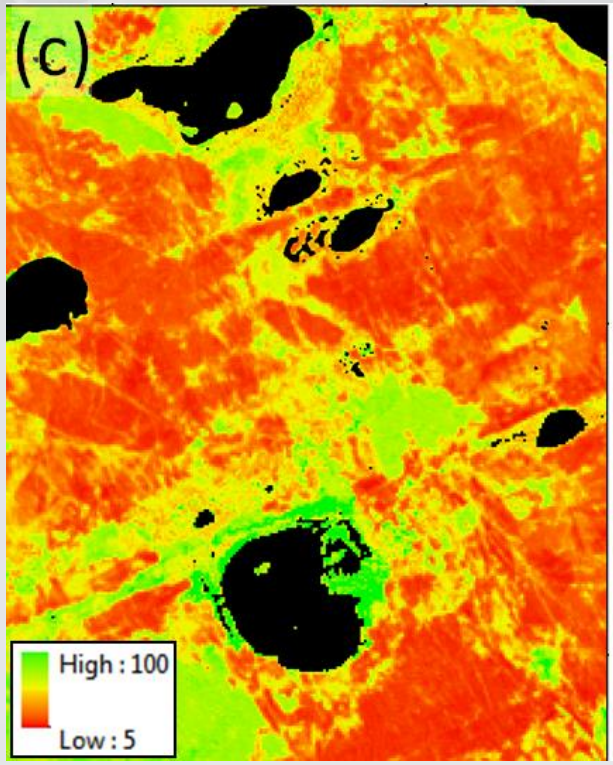
DISCUSSION:

APPLICATION OF MODELS OVER LARGER AREAS

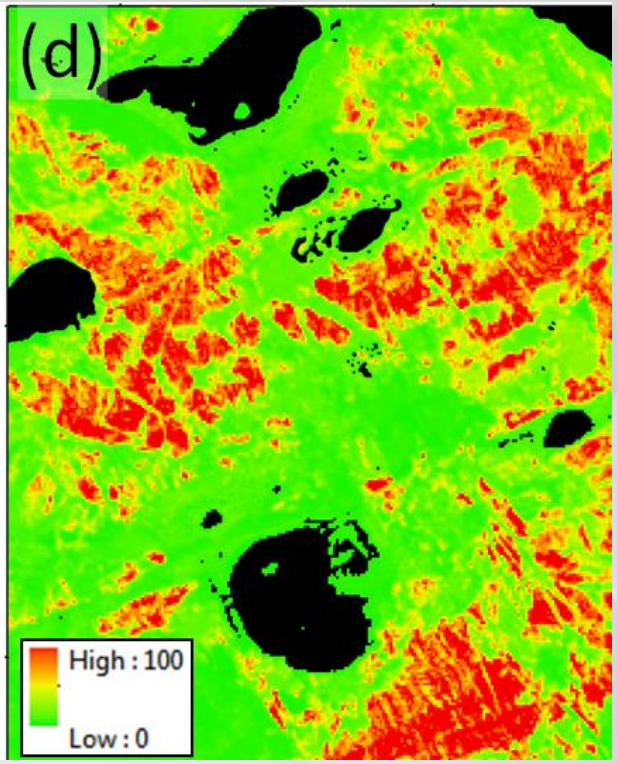
- Assign value-added, structural scales to Landsat indices



Post-burn Landsat 8



% residual vegetation



% charred surface

CONCLUSION:
MAIN FINDINGS

- UAS can provide cost-effective, geo-referenced imagery useful for operational/research burn severity work
  - Situational awareness; understanding landscape heterogeneity, field sampling; validation of unburned areas, interpreting satellite model residuals

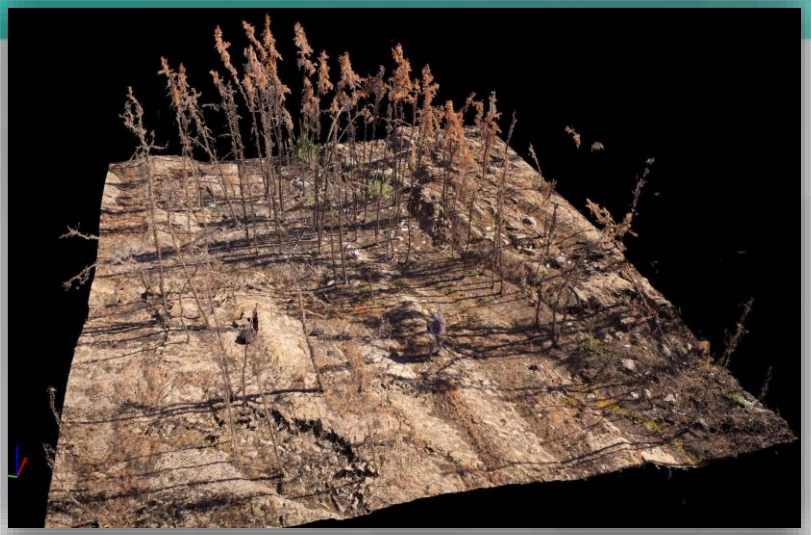
- Proof-of-concept: mechanism for up-scaling and assigning structural vegetation parameters to Landsat
  - Green Fraction and Char Fraction (5-8% RMSE)

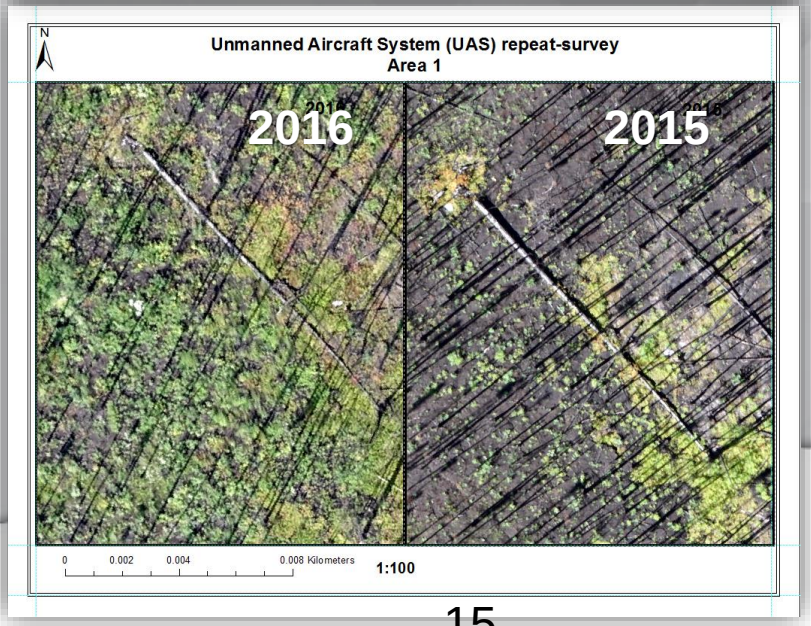
Fraser, Van der Sluijs, Hall (2017). Calibrating Satellite-Based Indices of Burn Severity from UAV-Derived Metrics of a Burned Boreal Forest in NWT, Canada. *Remote Sensing, 9*(3), 279; doi:10.3390/rs9030279

FUTURE WORK

- **Burn severity**
  - Individual CBI / BSI measures
  - Scorched crowns
  - Effect of illumination conditions
  - Stability of models at different dates
  - Light coloured ash

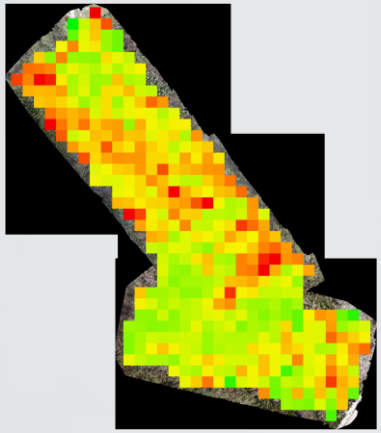
- **Regeneration / permafrost**
  - Repeat surveys
    - Model vegetation growth
    - Seedbank (mineral vs. duff)
    - Active layer changes





RESULTS:
PATTERN OF RESIDUALS

- Spatially clumped, not random
- **Underestimation**:
  green fractions in open unburned canopies (less shadowing)



- **Overestimation**:
  Standing scorched tree canopies or ground-layer of needles